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# Typology of Uncertainties in the Development Process of Product-Service Systems

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## Abstract

This paper investigates uncertainty in the development of Product-Service Systems (PSS) – a complex combination of product and services. This research is important because practitioners struggle with managing the high uncertainties arising from the complexity of parallel product and service development in compound clusters of stakeholders. Yet, scholars have not analyzed these challenges extensively. Based on a combination of innovation management and servitization literature a conceptual framework is offered, detailing five uncertainty types relevant for PSS-development: environmental, technical, organizational, resource and relational uncertainty. This research contributes to the servitization literature by broadening the body of knowledge and deriving suitable management practices.

**Keywords:** Product-Service System, Development Process, Uncertainty Management

## Introduction

The quest of differentiation and competitiveness lead to the new era of services. Recently customers focus more on the availability and capability of products than the actual acquisition of the artefact (Vasanth et al., 2012). These new concepts are known in the literature as product-service systems (PSS) and are a compound offerings comprised of products and supporting services (Mont, 2002). In response, companies increasingly seek to servitize their business models shifting the focus slowly from product-oriented to service-oriented offerings. This shift presents companies with changes in i.a. processes, culture, functions and relational capabilities (Barquet et al., 2013). Yet companies struggle to benefit from the potential profits of services. The high initial investments in extending to the service business lead to an increased service offering implying higher cost, while not generating the higher profit. This observation is also known as the “servitization paradox” (Gebauer et al., 2005)(Visnjic Kastalli and Van Looy, 2013).

One of the root causes is high uncertainty in the PSS development process (Sakao et al., 2009). Uncertainty is defined as a lack of knowledge, which may arise from not known, not definite or not reliable information (Kreye, 2017a). Uncertainty may manifest itself in a lack of competencies for the development (Wolfenstetter et al., 2015). This process is often characterized through high operational complexity of developing products and services in parallel (Zhang and Banerji, 2017), the high degree of stakeholder involvement (Martinez et al., 2010) and the long life cycles of PSS (Zhang and Banerji, 2017). Oftentimes this leads to market introductions of immature PSS or poor internal and external alignment (Alghisi and Saccani, 2015). The development of PSS differs strongly from traditional physical product development because the service component introduces new variables. Accordingly, the PSS development process comprises high uncertainty i.a. design requirements, cost estimations, market, economy and legal specifications (Kreye et al., 2014). Because of these varied sources of uncertainty, different uncertainty types need to be differentiated in the context of PSS development.

Research to date has delivered valuable insights on uncertainty in several contexts i.a. project management, innovation management, service delivery or radical innovation. Here, different uncertainty types have been defined which describe the domain from which the uncertainty emerges (O'Connor and Rice, 2013). However, the existence of uncertainty types in PSS development has not yet been investigated in depth. This paper aims to close this research gap by answering the following research question (RQ):

*What uncertainty types affect the development of product-service-systems?*

Based on an analysis of the existing literature on uncertainty in radical innovation and servitization, a framework is offered that categorizes uncertainty types. Specifically it is detailed, how technical, resource, organizational, relational and environmental uncertainties can affect the PSS development process. Although not all types are new to the literature, this framework contributes to theory-building in servitization because of the novel contextual embedding and adaptation of the uncertainty types to the PSS development process. It consolidates the key types of uncertainty and redefines them for the specific circumstances of the PSS development.

## **Research Design**

An exploratory literature review was conducted, comprising of a thematic analysis of the key contributions in the fields of PSS and uncertainty management. As PSS drastically change the existing markets and relationships within the stakeholder-network introducing a novel integration of products and services, they can be seen as a form of radical innovation (Tan, 2010). Therefore the literature research was further expanded to the field of radical innovation. The aim of the literature review is to create a rich understanding of the state-of-the-art literature to understand the uncertainty types arising within PSS development.

The analysis of PSS was conducted with search strings derived from the following keywords: “Product-Service System” or “PSS” (Mont, 2002)(Baines et al., 2007), “Servitization” (Baines et al., 2017), “Servitization Paradox” (Visnjic Kastalli and Van Looy, 2013), “IPS2” or “Industrial Product-Service System” (Martinez et al., 2010) and “Industrial Services” (Erkoyuncu et al., 2013). Similarly keywords were identified in the field of uncertainty management: “Risk and Uncertainty” (Reim et al., 2016), “Design Uncertainty” (Wynn et al., 2011), “Service Uncertainty” (Erkoyuncu et al., 2013), “Relational Uncertainty” (Kreye, 2017a), “Uncertainty Management” (Kreye and Balangalibun, 2015), “Project Uncertainty” (Atkinson et al., 2006). Lastly, the field of

radical innovation was explored with the initial set of the following keywords: “Radical Innovation” (Colombo et al., 2017), “Radical Innovation Management” (McDermott and O’Connor, 2002), “Innovation Uncertainty” (O’Connor and Rice, 2013). These keywords resembled the starting point of the research and were combined and refined throughout the search-process.

The in-depth analysis of the papers resulted in the identification of an uncertainty framework proposed by O’Connor and Rice (O’Connor and Rice, 2013) which details uncertainty types in radical innovation. As concluded previously that PSS can be seen as a form of radical innovation this framework was used as the conceptual basis for this research. It details four uncertainty types in terms of market, technical, resource and organizational uncertainty, and elaborates them from a radical innovation perspective. While market uncertainty refers to the appropriateness of the product for the market, technical uncertainty describes the degree to which scientific knowledge is understood and applied in the development process. Resource uncertainty is characterized by the insecurity of attracting the required financial and competency based resources for the project. Lastly, organizational uncertainty defines the organizational dynamism within the project as well as the project and its various internal or external constituencies. Nonetheless, PSS possess unique features beyond their radicalism by virtue of their long-term orientation (Tan, 2010), intensive stakeholder relationship and systemic complexity (Kreye et al., 2015). Thus the framework by O’Connor and Rice (2013) represents a valid starting point, while a complete redefinition and expansion on the basis of the extended literature review was needed to adapt it to the specific PSS development context. This redefinition and expansion led to a final framework incorporating five significant types of uncertainty in the context of PSS development.

### **A conceptual model of uncertainty in PSS development**

The proposed framework comprises of five uncertainty types: technical uncertainty, environmental uncertainty, organizational uncertainty, resource uncertainty and relational uncertainty. This section describes these five uncertainty types and their potential characterization within PSS development.

#### *Technical uncertainty*

Technical uncertainty describes the degree to which the engineering knowledge of the developed offering is well understood (O’Connor and Rice, 2013) as well as technological challenges caused by the long life cycle orientation of the PSS (Isaksson et al., 2009). It mainly revolves around techno-paradigmatic and complexity-related problems, in which high complexity and continued change call for high flexibility (Melander and Tell, 2014).

In PSS development, technical uncertainty may relate to the product, the service and their systemic integration:

- Product: uncertainty is related to the degree to which the foundational scientific knowledge is well understood and applied in form of a cost-efficient and manufacturable product (O’Connor and Rice, 2013). Moreover, it describes the challenge of integrating several components from multiple engineering disciplines e.g. IT, electrical engineering, mechanical engineering, mechatronic engineering, chemical engineering, metallurgical engineering (Wolfenstetter et al., 2015). Moreover, potential emergence of novel technologies and materials reducing the market value of the existing solution may threaten the PSS during it’s operation (Durugbo and Erkoyuncu, 2016). Technical uncertainty arises through coordinating and predicting technological development keeping the long-

term perspective in order to minimize the possibility of obsolescence of PSS components (Wolfenstetter et al., 2015).

- Service: uncertainty can relate to high variability of the service definition due to its customization (Nordin et al., 2011) and the uncertainty in forecasting of timing and scale of the service over a long life cycle span (Isaksson et al., 2009).
- Systemic integration between product and service: uncertainty aspects of the offering may be particularly challenging. On the one hand, managing all interfaces of the PSS design in the context of their integration can create high complexity due to high complicatedness (Benedettini and Neely, 2012). Technical uncertainty here arises through the task of complexity management. Specifically, it arises in foreseeing all possible combinations of product and service modules, keeping the mutual influences between them in mind, and the subsequent challenge to design all interfaces to be operational for all combinations predicted beforehand (Isaksson et al., 2009).

### *Organizational uncertainty*

Organizational uncertainty is defined as organizational dynamism both within the project, as well as between the project and its various internal or external stakeholders (O'Connor and Rice, 2013). It is reflected in terms of the organization's strategy, priorities and available resources (Kreye, 2016).

The challenges for PSS here may be similar to product development projects where stakeholder interests can vary, project planning and execution can be challenging, or functional interfaces within the organization can change (O'Connor and Rice). Additional organizational uncertainty may arise from the mix of cultures within an organization because PSS development integrates product-based and service-based functions and processes. Especially companies with a traditional product development mindset require a cultural change towards service provision. This shift may be challenging, for where the traditional focus was laid on efficiency and economies of scale, it now moves towards customization and flexibility in a service provision (Gebauer et al., 2005). In this setting, uncertainties arise because competence profiles, functions and processes need to be redefined and external partnerships reshaped according to the new requirements (Wolfenstetter et al., 2015).

Moreover, organizational uncertainty may arise through the complexity of project planning and execution of integrated product and service development (Wynn et al., 2011). It refers especially to the alignment of internal and external pre- or sub-projects (Ward and Chapman, 1995), uncertainty of forecasts (Atkinson et al., 2006) and goal definition (Atkinson et al., 2006). The alignment of pre- and sub-project carries uncertainty with respect to their completion and its knock-on effect on the overall development project (Pedersen and Agger Nielsen, 2011). Forecasting implies by definition uncertainty because the outcome cannot be known (Frühling, 2006). Lastly, challenges can arise in the context of the goal definition caused by negotiations and consensus building in the project. Potential hidden agendas as well as different stakeholder interpretation of qualitative and intangible results can inhibit the clear definition of the overall goal (Atkinson et al., 2006) and the supporting quantitative measures (Sanchez and Benoit, 2012).

Finally, high organizational uncertainty arises in critical factors like the pricing of the PSS at the bidding stage (Kreye et al., 2014) and accordingly the appropriateness of the cost and revenue model chosen for the PSS (Barquet et al., 2013). With respect to the pricing of the PSS, the bid is to enable the provider to win the contract as well as gain profit during the PSS operation. Root causes for uncertainty of pricing are i.a. connected

to uncertainty in cost-estimations from the contract fulfillment arising from e.g. varying spare parts costs or inflation rates on the financial markets (Kreye et al., 2014). With respect to the appropriateness of the cost and revenue model of the PSS challenges arise from the significant delay in cash flow of the manufacturer leading to an expansion of the amortization period (Mont et al., 2006). The provider needs to model and understand the cost and profitability implications of the long-term partnership (Neely, 2009). Here uncertainty arises from the shift towards performance-based pricing. Alike the aforementioned cost structure of setting the price at the bidding stage, uncertainty arise from forecasting the revenue stream has to be forecasted as well as the determination to split the revenue split among the value network (Barquet et al., 2013).

#### *Relational uncertainty*

Relational uncertainty refers to the inability to predict the partner's future behavior and level of cooperation offered (Kreye, 2017a). This uncertainty type has not been elaborated in the radical innovation literature but originates from descriptions of operating PSS in service dyads between provider and customer. In the present framework it has been highlighted as a core challenge to PSS providers because of the high degree of stakeholder involvement in the development process as well as the large size of the internal and external stakeholder network (Baines et al., 2007).

Relational uncertainty may arise in PSS development if new business models are co-created with customer or supplier (Kreye et al., 2015). Because the process of co-creation in PSS development requires more sophisticated relationships (Isaksson et al., 2009) than traditional product development, relational uncertainty is reflected in the willingness, availability and ability of the partners to collaborate (Atkinson et al., 2006). These more sophisticated relationships demand i.a. increased information exchange, joint realization of innovations and especially, fast addressment of occurring disagreements and problems. Accordingly, relational uncertainty may originate from e.g. lack of trust, low commitment, deficient information sharing as well as a disjoint approach to problem solving (Kreye et al., 2015) resulting in a partner's inability to perceive or deliver the service (Kreye, 2017a), i.e. weak inter-personal or inter-organizational relationships (Kreye et al., 2015).

Moreover, relational uncertainty may arise from the unpredictability of the partner's actions due to lack of knowledge about his abilities and intentions. Causes may lie in a low degree of reliability and quality of the partner's work, or a low level of goal alignment (Kreye and Balangalibun, 2015). Relational uncertainty arising from the partner's work may be connected to potential unwillingness of the partner to shift to the new business model of integrated offerings. It may further originate from the challenge of the required performance and processes alignment across organizations (Martinez et al., 2010) specific for PSS development. The level of goal alignment refers to the extent to which the partner's objectives are aligned with each other and the overall project goal (Kreye and Balangalibun, 2015). As such, the customers may aim for fast and flexible reactions in order to satisfy the dynamically changing needs, whereas a provider aims for internal optimization of structures. Moreover, the goals need to be aligned with the suppliers in the value network. Especially in international settings it may be difficult to balance the alignment with flexible reaction to changes in markets (Wolfenstetter et al., 2015). It can be reflected in a lack of clarifying the specifications of the project, complexity of the project processes or unexpected bias of the decision makers (Kreye and Balangalibun, 2015).

Relational uncertainty in the context of PSS development may also arise from service contracting. Servitization contracts are highly complex and not all possible contingencies

may be foreseen (Toffel, 2008). This creates “grey areas” in contracts (Martinez et al., 2010) and thus in practice contracts are often incomplete (Kreye et al., 2015). Since PSS build upon a long-term provider-customer relationship the contracting capabilities of both parties are crucial (Kreye, 2017a). Especially the split between the collaboration partners of i.a. costs, risk and intellectual property (Isaksson et al., 2009) is crucial. Relational uncertainty may arise due to potentially unforeseen opportunistic behavior in the definition of this split of responsibility during the contracting negotiation of one of the contracting partners.

Lastly, additional uncertainty can arise in the relationship with the customer because their needs may change between PSS development and PSS operation (Wolfenstetter et al., 2015) leading to changes in scope of the collaboration. Here, willingness to adapt the new business model to the new customer needs (Martinez et al., 2010) cause uncertainties in the relationship. Especially, since PSS implies a long-term relationship between the provider and the customer, market changes resulting in changed customer requirement, signifies uncertainty to continuously redefine and modify the existing business model (Wolfenstetter et al., 2015).

#### *Resource uncertainty*

Resource uncertainty refers to challenges arising from attracting the required resources (O'Connor and Rice, 2013). Resources may be defined as both tangible and intangible entities (Kreye et al., 2015). They may consist of competences, critical information, financial resources as well as other resources required. Uncertainty connected with e.g. the required competencies, can be related to internal and external employee fluctuation involved in the PSS development (Zhang and Banerji, 2017), the technical engineering and managerial capabilities (Wolfenstetter et al., 2015) or the general novelty and inexperience of a particular activity (Atkinson et al., 2006).

The high degree of complexity of PSS (Zhang and Banerji, 2017) and tailoring to the customer's needs typically requires high amounts (Benedettini et al., 2015) or very specific resources (Visnjic Kastalli and Van Looy, 2013). Since often the type or the amount of the diverse resources required are not entirely existent in the providing company, it faces the uncertainty of attracting them externally during the PSS development. This means that resource attraction can be particularly challenging in PSS development caused by the uncertainty of existence or availability of these specific resources needed. Moreover, challenges are caused by the complexity management of the resources required come from diverse internal and external sources and disciplines (Wolfenstetter et al., 2015).

Moreover, the previously described process of co-creation involves the customer as crucial operant resource. The customer in the PSS development does therefore not only create relational but also resource uncertainty. The relational uncertainty with the customer exists through the unpredictability of the partners actions in this very sophisticated relationship. But as the customer is also part of the value creation his contribution is unique and difficult to imitate (Benedettini et al., 2015) as the PSS is tailored specifically to his needs. Therefore the customer also creates resource uncertainties as the project depends to a high degree on his input.

Lastly, the previously described major change in cash flow of PSS operation often requires major initial investments. Financial and accounting practices need to be adapted and the necessary financial resources attracted. Resource uncertainty arises from the need to convince external financial partners of the PSS concept to bridge the initial period before the break-even point (Barquet et al., 2013).

### *Environmental uncertainty*

Environmental uncertainty refers to lack of knowledge about the external environment (Milliken, 1987). It includes the market uncertainty described by O'Connor and Rice (2013) in the context of radical innovation. The market uncertainty refers to the degree to which customer's needs are well understood and converted into a market application, appropriate markets are defined and a suitable business model chosen (O'Connor and Rice, 2013). Predicting these external factors and their effect on the PSS can pose a challenge in PSS development. As for the context of radical innovations market uncertainty arising from a lack of understanding customer needs and the intended market segment is one of the core challenges of PSS development (Spath and Demuss, 2001). Defining this new type of value proposition and the surrounding business model focused on long-term relationships and no shift in ownership can encounter challenges in form of e.g. high mental barriers once reaching the markets – especially if the offering is not co-created (Lay, 2014). Moreover, the long life cycles create challenges for the PSS development to predict and incorporate all necessary user functionalities across the entire PSS life cycle (Wolfenstetter et al., 2015).

Yet, the long life cycles affect the PSS development in a larger perspective than the pure market uncertainty. Here long-term macro environmental developments may enhance or threaten the PSS business model (Kreye, 2017b). These developments may comprise of competitor's actions (Wolfenstetter et al., 2015), legal developments and changing regulations (Kreye, 2017b), technological development with respect to obsolescence (Reim et al., 2016) as well as large macro-economic financial uncertainty (Wolfenstetter et al., 2015). During the development phase, these aspects have to be taken into account to design the PSS as resilient to macro environmental changes as possible. As such, uncertainty arises in predicting the competitor actions to reach a high degree of differentiation (Nordin et al., 2011) during the PSS development. Moreover, threats or opportunities opposed through legal or regulatory developments as well as large macro-economic financial changes have to be considered. Legal and regulatory uncertainties may result from changes in e.g. safety regulations or political developments (Kreye, 2017b). Financial uncertainty can occur through e.g. inflation, a financial crisis and changes in exchange rates (Wolfenstetter et al., 2015). Similarly, the threat of technological obsolescence must be encountered in the PSS development. In the context of the macro environmental developments the uncertainty about obsolescence refers to the knowledge gained through the continual scanning of technological developments (Garud and Nayyar, 2012) before, during and after the PSS development. This process implies to the constant uncertainty about completeness, ambiguity or reliability of the information found (Wynn et al., 2011).

Figure 1 summarizes the conceptual framework of the five potential uncertainty types in PSS development.



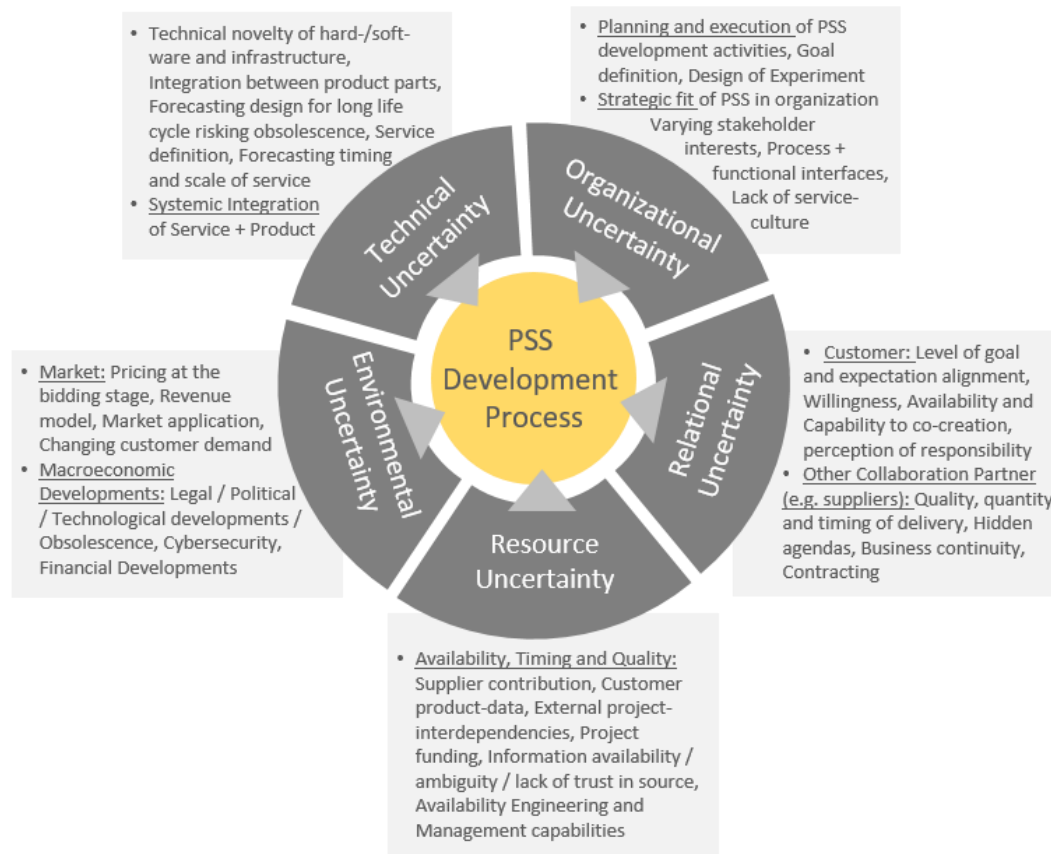


Figure 1 Five potential uncertainty types in PSS development

## Implications and Conclusion

This paper explored the research question: What uncertainty types affect the development of product-service-systems? Based on an exploratory literature review in the areas of radical innovation, uncertainty and servitization, a framework of uncertainty typology is proposed. The framework distinguishes five core uncertainty types affecting the PSS development, in the form of technical, organizational, relational, resource and environmental uncertainty. Although all uncertainty types have already been discussed in the literature, they have not been explored in the specific PSS development context.

The proposed framework of uncertainty in PSS development contributes to the PSS literature by providing a theoretically founded typology of uncertainties affecting the development process of PSS offerings. The proposed framework is distinct for PSS development while being based on two main literature streams in the areas of radical innovation and PSS.

This research has implications for managers of PSS providers. The proposed framework draws attention to the distinct circumstances of PSS development and the main, general causes of uncertainty leading to the “servitization paradox”. Accordingly, companies may select project managers with suitable uncertainty management skills to appropriately identify and manage the uncertainties occurring during the project. The categorization aids in guiding them through a holistic uncertainty assessment of the PSS development project.

This paper contributes to the PSS and innovation literature by providing a theoretically founded typology of uncertainties occurring during the PSS development process. It unites all relevant drivers for uncertainty in one holistic overview and adapts them to the specific PSS development context. It moreover contributes to generate a deep

understanding of the main causes of uncertainty. Lastly, it creates awareness for the distinct and challenging circumstances of PSS development.

As this paper bases on retrospective empirical studies as well as purely academic analysis the empirical validation is a major limitation for the validity of the framework. Hence future research may validate this typology through empirical cases of PSS development to verify and deepen the insights in this regard.

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